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Shima et al.

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(54) **VEHICLE ROOF STRUCTURE**

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B62D 25/06	(2006.01)
B62D 29/00	(2006.01)
B62D 29/04	(2006.01)
H01L 31/048	(2014.01)

(52) **U.S. Cl.**

CPC ***B60K 16/00*** (2013.01); ***B62D 25/06*** (2013.01); ***B62D 29/005*** (2013.01); ***B62D 29/043*** (2013.01); ***H01L 31/048*** (2013.01); ***H02S 10/40*** (2014.12); *B60K 2016/003* (2013.01)

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CPC Y02T 10/7083; Y02T 10/90; Y02B 10/20; Y02B 10/12; B60L 8/003; Y02E 10/50; H01L 31/048; H02S 20/23

USPC 296/210, 211, 214, 215; 126/621, 623, 126/622; 136/244, 251, 291, 245, 246; 180/2.2; 320/101; 52/173.3; 454/900

See application file for complete search history.

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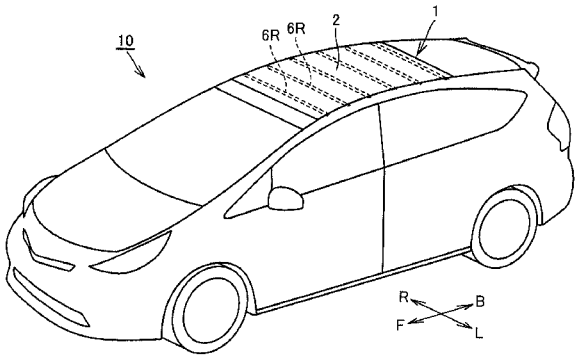
(57) **ABSTRACT**

A vehicle roof structure includes a solar cell unit having a plurality of solar cells arranged in a planar form at intervals from one another, a roof panel disposed to cover the solar cell unit from above, and a reinforcing member disposed under the solar cell unit. The reinforcing member supports the solar cell unit with a plurality of supporting parts provided at positions corresponding to the intervals left between the plurality of solar cells. The vehicle roof structure can prevent the solar cells from breaking down under stress.

10 Claims, 6 Drawing Sheets



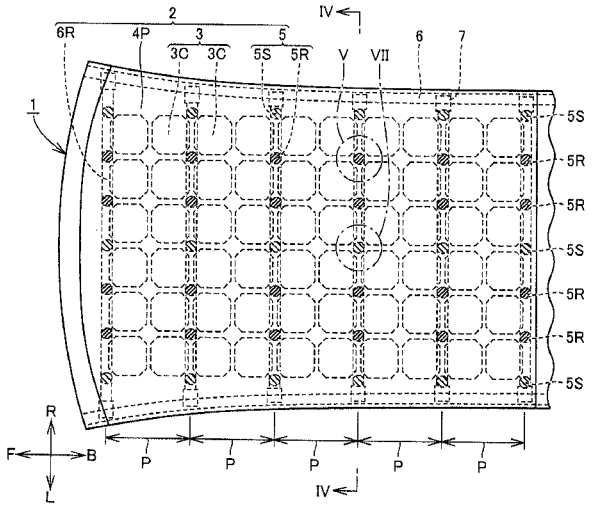


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FIG.1

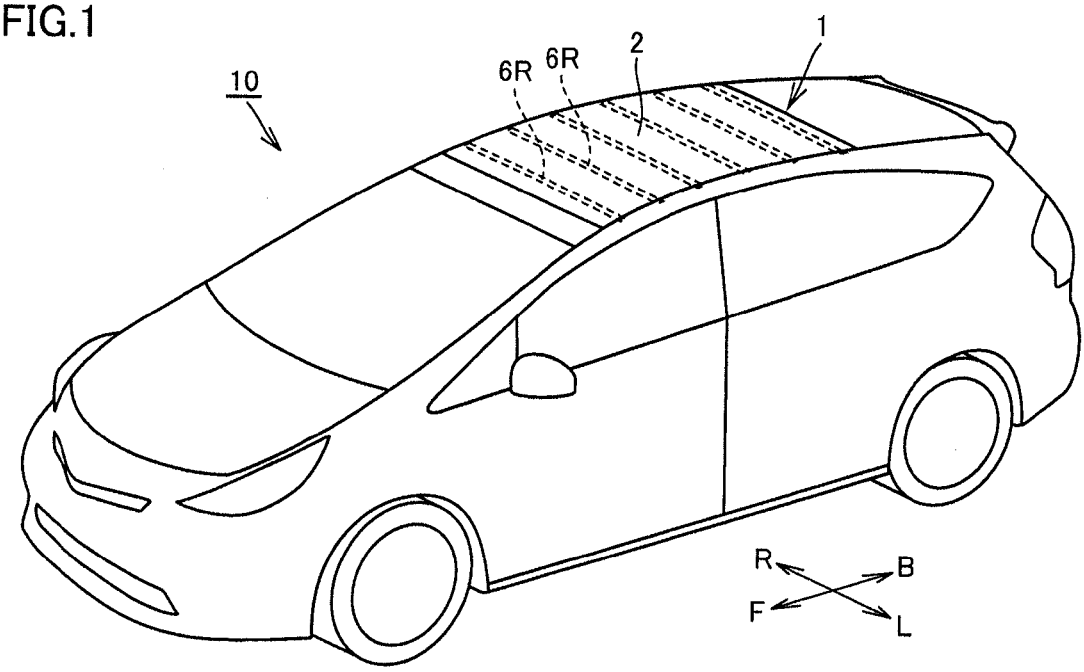

10
6R
6R
2
1
R
B
F
L

FIG.2

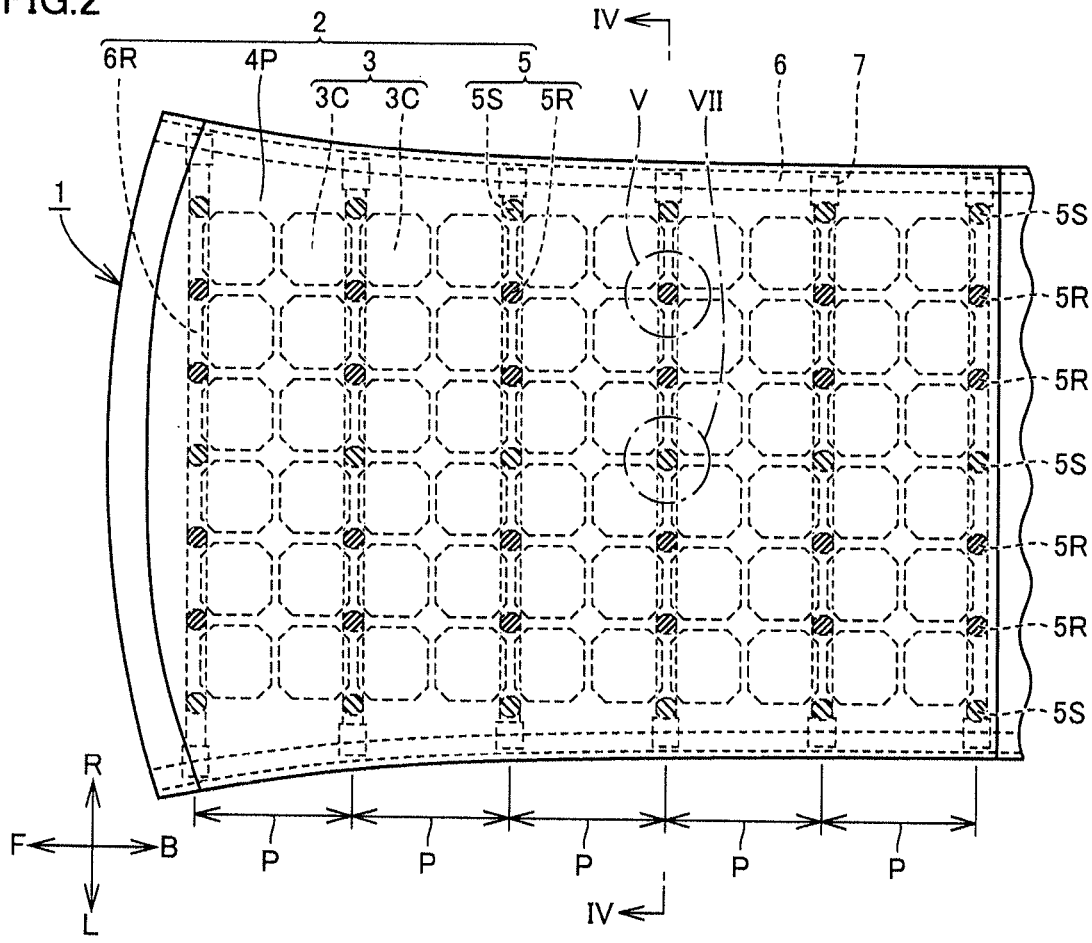

2
6R
4P
3
3C
3C
5
5S
5R
IV
V
VII
6
7
1
5S
5R
5R
5S
5R
5R
5S
R
F
B
L
P
P
P
P
P
IV

FIG.3

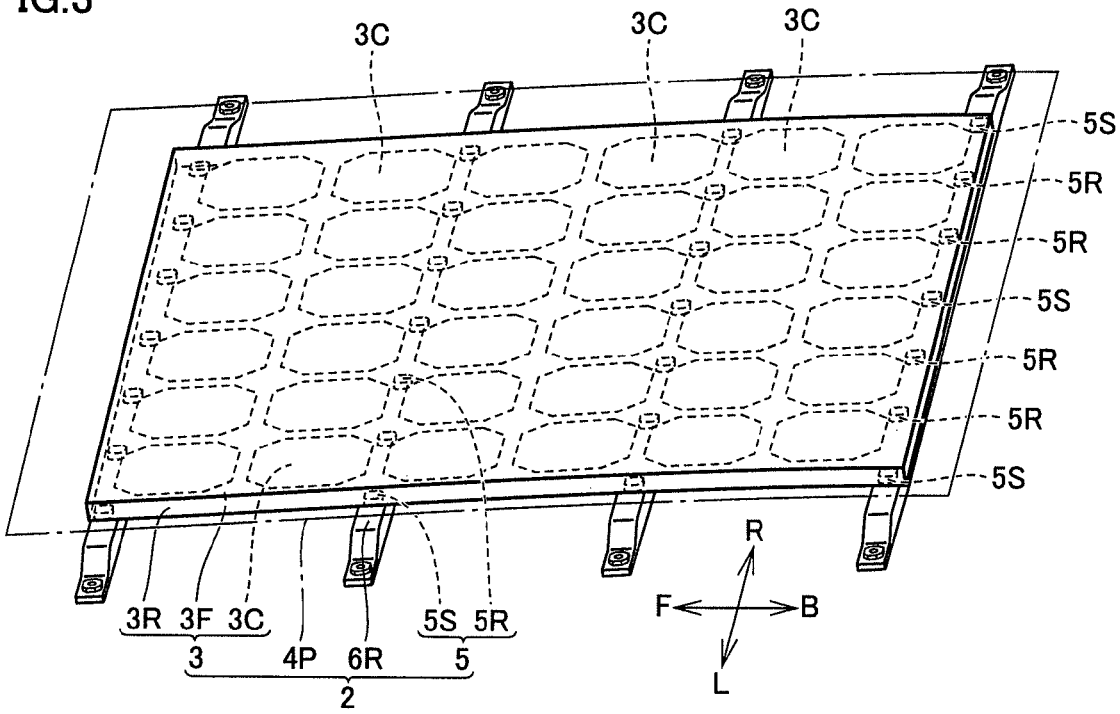

3C
3C
3C
5S
5R
5R
5S
5R
5R
5S
R
F
B
L
3R 3F 3C
5S 5R
3
4P
6R
5
2

FIG.4

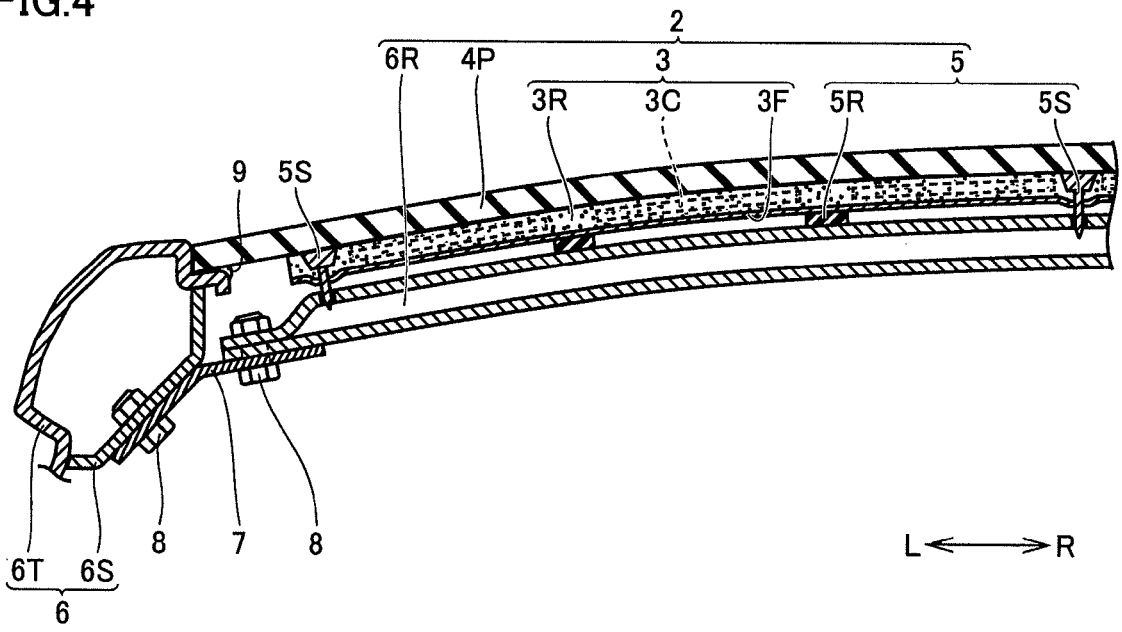

2
6R
4P
3
5
3R
3C
3F
5R
5S
9
5S
8
7
8
6T
6S
6
L
R

FIG.5

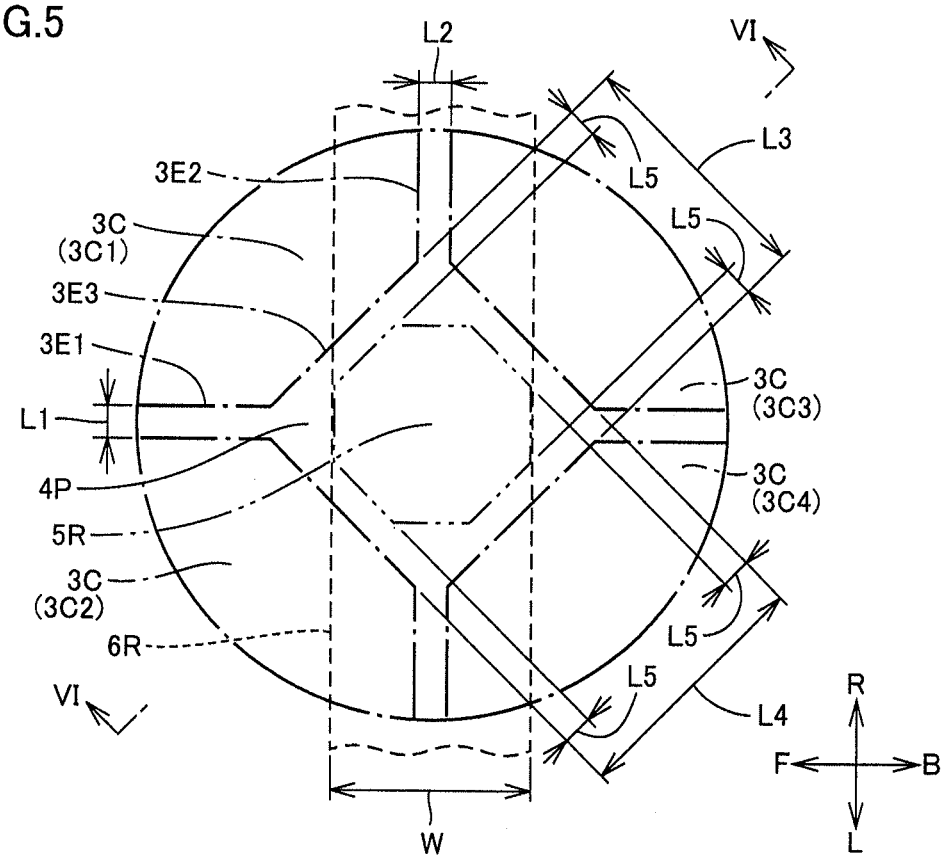

L2
VI
L3
L5
L5
3E2
3C
(3C1)
3E3
3E1
L1
4P
5R
3C
(3C2)
6R
3C
(3C3)
3C
(3C4)
L5
L5
L4
VI
R
F
B
L
W

FIG.6

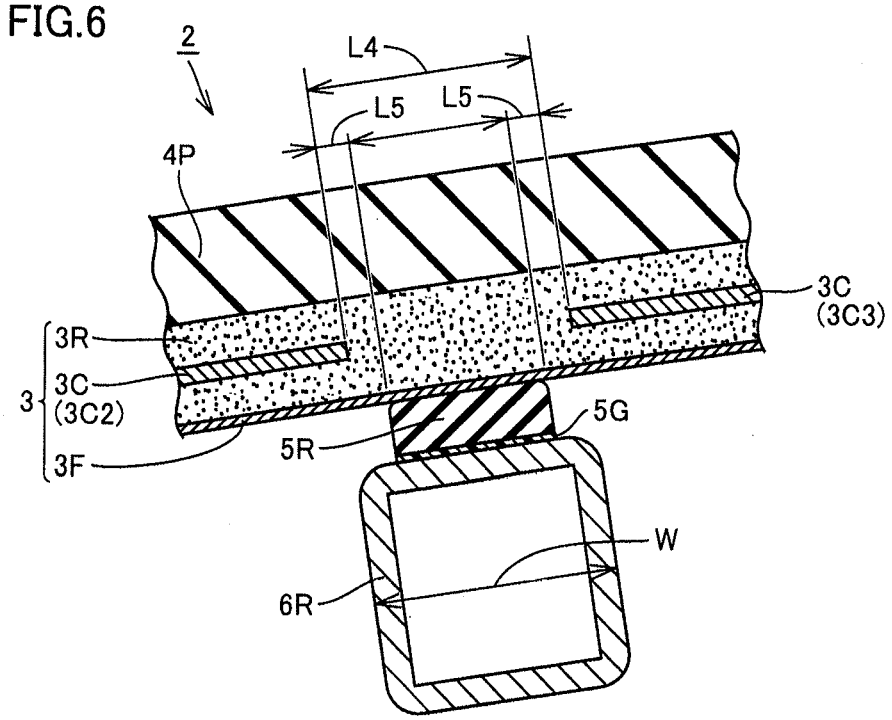

2
L4
L5
L5
4P
3C
(3C3)
3R
3C
(3C2)
3F
3
5G
5R
W
6R

FIG.7

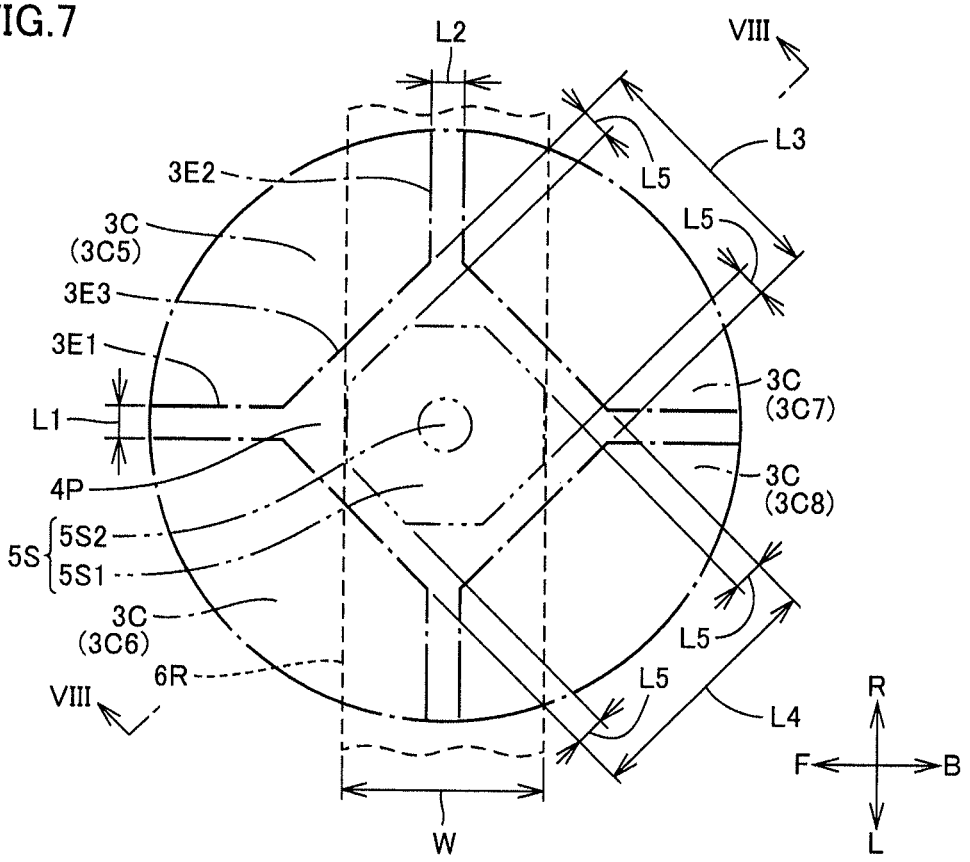

L2
VIII
L3
L5
3E2
3C
(3C5)
3E3
3E1
L1
4P
5S
5S2
5S1
3C
(3C6)
6R
VIII
3C
(3C7)
3C
(3C8)
L5
L5
L5
L4
R
F
B
L
W

FIG.8

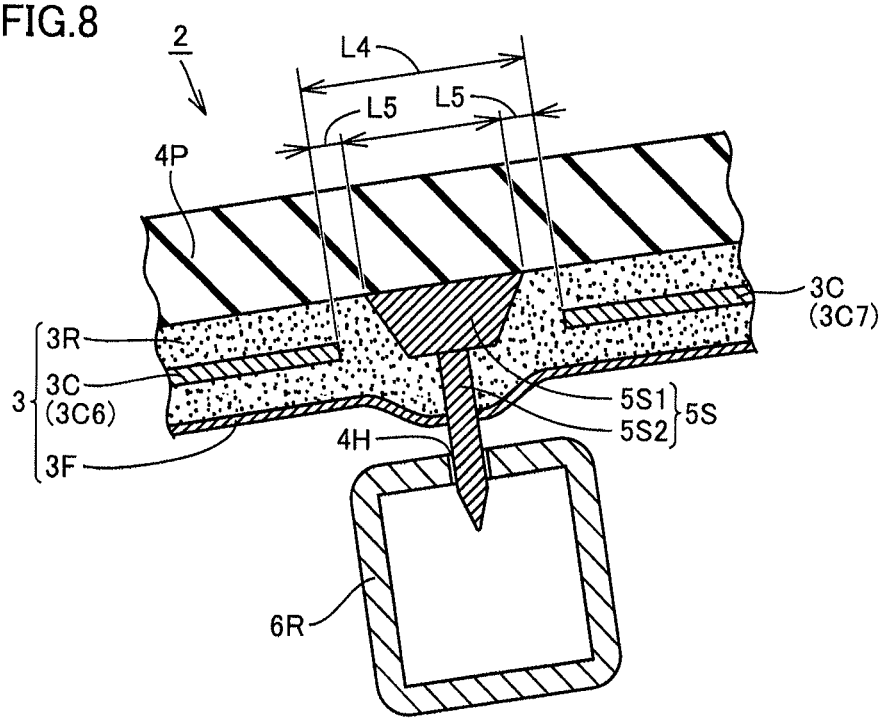

2
L4
L5
L5
4P
3C
(3C7)
3R
3
3C
(3C6)
3F
5S1
5S2
5S
4H
6R

FIG.9

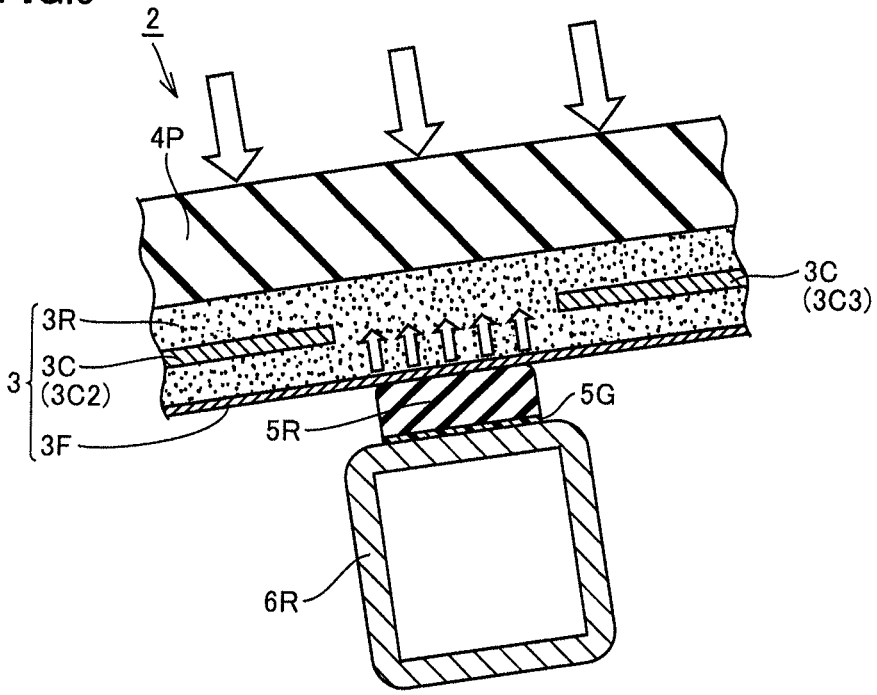

2
4P
3C
(3C3)
3R
3C
(3C2)
3
3F
5G
5R
6R

FIG.10

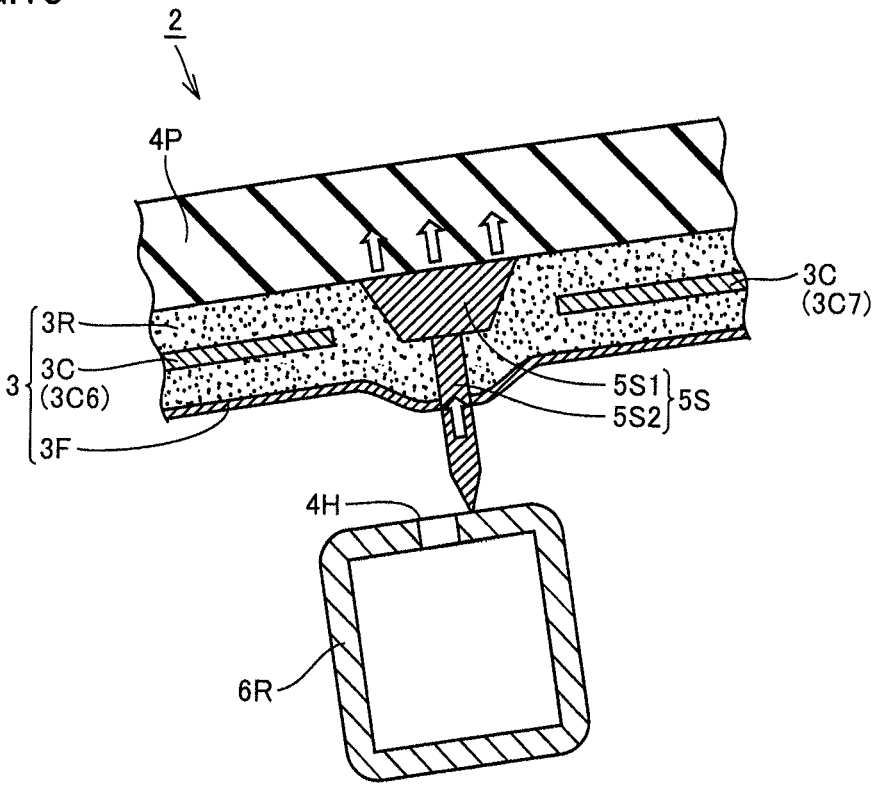

2
4P
3C
(3C7)
3R
3C
(3C6)
3
3F
5S1
5S2
5S
4H
6R

FIG.11

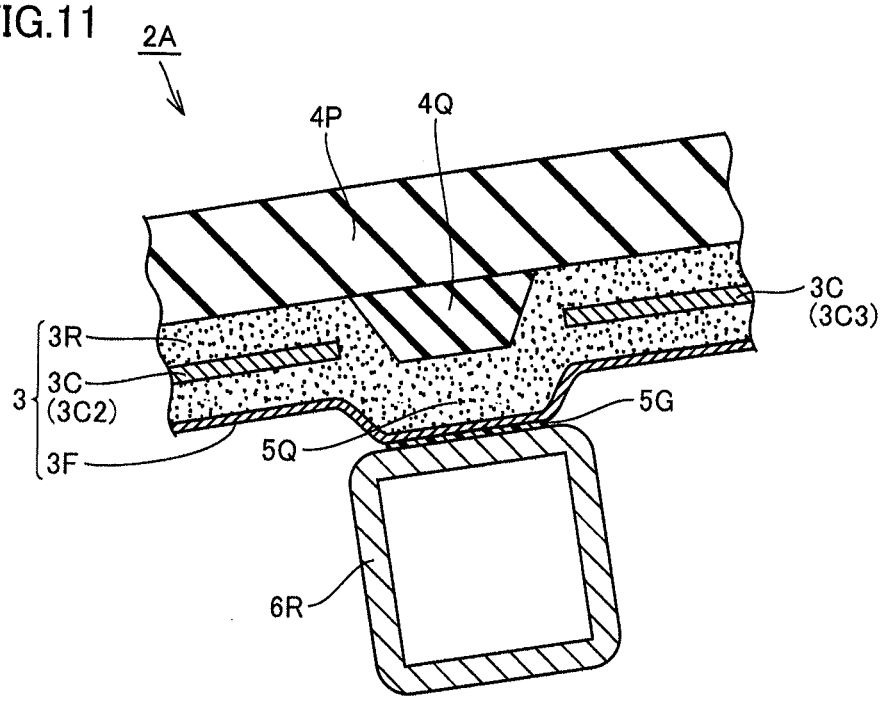
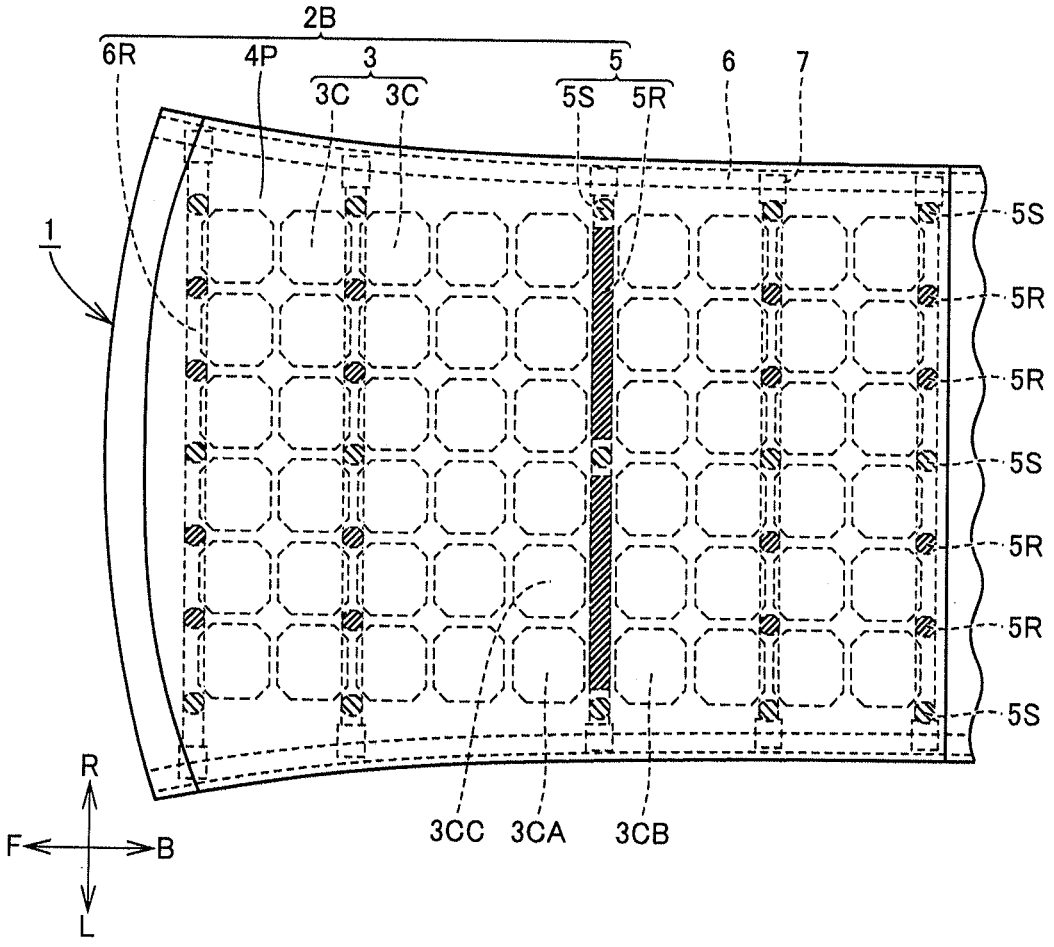

2A
4P
4Q
3C
(3C3)
3R
3
3C
(3C2)
3F
5G
5Q
6R

FIG.12


2B
6R
4P
3
3C
3C
5
5S
5R
6
7
1
5S
5R
5R
5S
5R
5R
5S
3CC
3CA
3CB
R
F
B
L

VEHICLE ROOF STRUCTURE

This nonprovisional application is based on Japanese Patent Application No. 2013-246419 filed on Nov. 28, 2013 with the Japan Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a vehicle roof structure having solar cells.

2. Description of the Background Art

As disclosed in Japanese Patent Laying-Open No. 11-157342, a vehicle roof structure equipped with solar cells is known. The solar cells disclosed in the publication include a plurality of solar cells arranged in a planar form. The plurality of solar cells are sealed with resin on a glass panel. The roof structure including the plurality of solar cells sealed with resin on the glass panel are supported by reinforcing members with spacers interposed therebetween on the solar cells side.

SUMMARY OF THE INVENTION

Loads are imposed on the vehicle roof by snow coverage, car washing or the like. With a structure in which spacers, cushion members and the like are provided directly under solar cells to support a roof structure as described in Japanese Patent Laying-Open No. 11-157342, when a load is imposed on the roof, the load could be input to the solar cells through the spacer members or the like, so that the solar cells may break down. In this case, the solar cells can no longer generate electric power appropriately.

The present invention was made in view of the above actual circumstances, and has an object to provide a vehicle roof structure that can prevent solar cells from breaking down under stress.

A vehicle roof structure based on the present invention includes a solar cell unit having a plurality of solar cells arranged in a planar form at intervals from one another and a sealing resin sealing the plurality of solar cells, a roof panel having transparency and disposed to cover the solar cell unit from above, and a reinforcing member disposed under the solar cell unit. The reinforcing member supports the solar cell unit with a plurality of supporting parts provided at positions corresponding to the intervals left between the plurality of solar cells.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing a vehicle according to an embodiment.

FIG. **2** is a partial plan view schematically showing a vehicle roof according to the embodiment.

FIG. **3** is a perspective view schematically showing a vehicle roof structure provided for the vehicle according to the embodiment.

FIG. **4** is cross sectional view taken along the line IV-IV in FIG. **2**.

FIG. **5** is an enlarged view showing a region encircled with the line V in FIG. **2**.

FIG. **6** is a cross sectional view taken along the line VI-VI in FIG. **5**.

FIG. **7** an enlarged view showing a region encircled with the line VII in FIG. **2**.

FIG. **8** is a cross sectional view taken along the line VIII-VIII in FIG. **7**.

FIG. **9** is a cross sectional view showing a state when the vehicle roof structure provided for the vehicle according to the embodiment is put under a load.

FIG. **10** is another cross sectional view showing a state when the vehicle roof structure provided for the vehicle according to the embodiment is put under a load.

FIG. **11** is a cross sectional view showing a vehicle roof structure according to a first variation of the embodiment.

FIG. **12** is a plan view showing a vehicle roof structure according to a second variation of the embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, an embodiment will be described with reference to the drawings. When the number, an amount or the like is mentioned, the scope of the present invention is not necessarily limited to that number, that amount or the like, unless otherwise specified. The same or corresponding parts have the same reference characters allotted, and detailed description thereof will not be repeated.

FIG. **1** is a perspective view showing a vehicle **10** according to an embodiment. An arrow L in the drawing indicates the left direction of the vehicle, and an arrow R indicates the right direction of the vehicle. The direction along the arrows L and R is the width direction of the vehicle. An arrow F indicates the forward direction of the vehicle, and an arrow B indicates the backward direction of the vehicle. The direction along the arrows F and B is the longitudinal direction of the vehicle. These apply in common to FIGS. **2** to **5**, **7** and **12** which will be described later.

As shown in FIG. **1**, the vehicle **10** includes a vehicle roof structure **2** provided for a roof **1**. FIG. **2** is a partial plan view schematically showing the roof **1** of the vehicle **10**. As shown in FIG. **2**, the roof **1** of the vehicle includes the vehicle roof structure **2** attached between roof side rails **6** arranged on the right and left.

FIG. **3** is a perspective view schematically showing the vehicle roof structure **2**. FIG. **4** is a cross sectional view taken along the line Iv-Iv in FIG. **2**. As shown in FIGS. **2** to **4**, the vehicle roof structure **2** includes a solar cell unit **3**, a roof panel **4**P, a plurality of reinforcements **6**R (reinforcing members), and a plurality of supporting parts **5**. The solar cell unit **3** includes a plurality of solar cells **3**C, transparent resin **3**R as a sealing resin (FIGS. **3** and **4**), and a film **3**F (FIGS. **3** and **4**) provided on the lower surface side of the transparent resin **3**R.

The plurality of solar cells **3**C are arranged in a planar form at intervals from one another, and are connected to one another in series and in parallel to constitute a battery. In the present embodiment, each of the solar cells **3**C has a generally octagonal shape with four corners of a rectangular panel slightly cut away in a plan view. The plurality of solar cells **3**C are arranged in a matrix form such that cutaway parts of adjacent cells are adjacent to each other. Each of the solar cells **3**C includes a silicon-based crystal, and has characteristics of easily breaking down in the case of receiving an excessive bending load. The size, shape and number of the solar cells **3**C included in the solar cell unit **3**, as well as the interval between the solar cells **3**C adjacent to each other are configured such that the mounting density of the solar cells **3**C is as large as possible in the roof panel **4**P of the vehicle

roof structure **2**. That is, the solar cells **3**C may have a quadrangular shape, such as a square or a rectangle, or the solar cells **3**C may have a disc shape. It is noted that, as for the interval between the solar cells **3**C adjacent to each other, its minimum required distance is set in accordance with various conditions, such as the wiring space of the solar cells **3**C and a heat shrinkage absorption margin of the sealing resin.

The transparent resin **3**R as the sealing resin covers internal members within a module, such as the solar cells **3**C which are power generation elements and wiring lines, to protect the internal members from permeation of water content and impacts. As the transparent resin **3**R, a publicly known sealing resin material, such as EVA (ethylene acetic acid copolymer), PVB (polyvinyl butyral) or a silicone resin, is used. The transparent resin **3**R seals the plurality of solar cells **3**C, so that the plurality of solar cells **3**C are adhered to the lower surface of the roof panel **4**P (see FIG. **4**). The film **3**F is provided on the transparent resin **3**R on the opposite side of the roof panel **4**P. The roof panel **4**P, the transparent resin **3**R including the solar cells **3**C, and the film **3**F constitute an integrated unit.

The roof panel **4**P is a member constituting part of the upper surface of the roof **1** of the vehicle **10**, and has a plate-like shape. In FIG. **3**, the roof panel **4**P is schematically indicated by an alternate long and short dash line for the sake of convenience. The upper surface of the roof panel **4**P constitutes the outer surface of the vehicle, and is exposed to the outside air. The roof panel **4**P covers the solar cell unit **3** from above by its lower surface. In the present embodiment, a resin panel having transparency is used as the roof panel **4**P. Examples of a resin material constituting the roof panel **4**P include a polycarbonate resin, an acrylic resin, a PET resin, and a vinyl chloride resin, which are appropriately selected in accordance with a use environment. Sunlight passes through the roof panel **4**P to reach each of the solar cells **3**C in the solar cell unit **3**. A hard coating or the like is applied to the outer surface of the roof panel **4**P made of a resin to increase damage resistance. Although the roof panel **4**P may be implemented by a glass panel, a resin panel when used for the roof panel **4**P can advantageously make the total weight of the roof lighter than in the case of using the glass panel.

The following method can be adopted, for example, in order to bond the plurality of solar cells **3**C to the lower surface of the roof panel **4**P (the surface opposite to the outer surface of the vehicle). First, the lower surface of the roof panel **4**P is placed upward, and a sheet material is disposed on the roof panel **4**P. This sheet material is a member made of thermoplastic resin having transparency (e.g., EVA), and constitutes the sealing resin. Next, the plurality of solar cells **3**C are arranged in a planar form on the sheet material. Another sheet material is disposed to cover the plurality of solar cells **3**C. This sheet material is also a member made of thermoplastic resin having transparency (e.g., EVA), and constitutes the sealing resin. Then, the film **3**F is disposed to cover that sheet material.

Next, the above two sheet materials are subjected to vacuum heating between the film **3**F and the roof panel **4**P. The two sheet materials are melted. By stopping vacuum heating, the two sheet materials solidify to form the transparent resin as the sealing resin (see the sealing resin **3**R in FIG. **4**). The plurality of solar cells **3**C are sealed with the sealing resin and adhered to the roof panel **4**P.

The reinforcements **6**R as the reinforcing members each have a shape extending in the form of rod, and are disposed below the solar cell unit **3**. The reinforcements **6**R support the solar cell unit **3** from below (from the vehicle cabin side) with the plurality of supporting parts **5** (cushion rubbers **5**R) which will be described next. The reinforcements **6**R are each implemented by a member of metal, such as iron, and have a shape of rectangular tube (see FIG. **3**). The reinforcements **6**R each extend in the vehicle width direction, and are arranged in parallel at intervals P (FIG. **2**) from one another in the vehicle longitudinal direction. The interval P is 300 mm, for example.

The plurality of supporting parts **5** include a plurality of cushion rubbers **5**R (see also FIG. **6**) and a plurality of positioning parts **5**S (see also FIG. **8**), which are provided between the transparent resin **3**R (more specifically, the film **3**F) of the solar cell unit **3** and the reinforcements **6**R. Hereinafter, the shape and arrangement of the cushion rubbers **5**R and the positioning parts **5**S will be described.

(Cushion Rubber **5**R)

FIG. **5** is an enlarged view showing a region encircled with the line V in FIG. **2**. FIG. **5** illustrates four of the plurality of solar cells **3**C (**3**C**1** to **3**C**4**) arranged in two rows and two columns, the reinforcement **6**R having a width W and extending in the vehicle width direction, the roof panel **4**P provided to cover the solar cell unit **3** (see FIG. **4**), and the cushion rubbers **5**R provided between the solar cell unit **3** and the reinforcements **6**R. FIG. **6** is a cross sectional view taken along the line VI-VI in FIG. **5**.

Referring to FIGS. **5** and **6**, as described above, each of the plurality of solar cells **3**C has a generally octagonal shape in a plan view, and are arranged in a planar form at intervals from one another. Each of the plurality of solar cells **3**C has an outer edge **3**E**1** extending in the vehicle longitudinal direction, an outer edge **3**E**2** extending in the vehicle width direction, and an outer edge **3**E**3** formed between the outer edge **3**E**1** and the outer edge **3**E**2** and extending in an oblique direction.

The two solar cells **3**C**1** and **3**C**2** are adjacent to each other in the vehicle width direction. An interval L**1** is left between the outer edges **3**E**1** of the solar cells **3**C**1** and **3**C**2**. The two solar cells **3**C**3** and **3**C**4** are also adjacent to each other in the vehicle width direction. The interval L**1** is also left between the outer edges **3**E**1** of the solar cells **3**C**3** and **3**C**4**.

The two solar cells **3**C**1** and **3**C**3** are adjacent to each other in the vehicle longitudinal direction. An interval L**2** is left between the outer edges **3**E**2** of the solar cells **3**C**1** and **3**C**3**. The two solar cells **3**C**2** and **3**C**4** are also adjacent to each other in the vehicle longitudinal direction. The interval L**2** is also left between the outer edges **3**E**2** of the solar cells **3**C**2** and **3**C**4**.

The two solar cells **3**C**1** and **3**C**4** are adjacent to each other in an oblique direction. An interval L**3** is left between the outer edges **3**E**3** of the solar cells **3**C**1** and **3**C**4**. The two solar cells **3**C**2** and **3**C**3** are also adjacent to each other in an oblique direction. An interval L**4** is left between the outer edges **3**E**3** of the solar cells **3**C**2** and **3**C**3**. That is, the plurality of solar cells **3**C disposed in a matrix form are arranged such that the cutaway parts of adjacent cells are adjacent to each other, and therefore, relatively large clearances are left between the above-mentioned four solar cells **3**C**1**, **3**C**2**, **3**C**3**, and **3**C**4** by means of the cutaway parts.

The intervals L**1** and L**2** have a dimension of 3 mm to 5 mm, for example. This value is optimized in view of the wiring operation of connecting the solar cells together, the degree of heat shrinkage of the transparent resin **3**R when solidifying a transparent thermoplastic resin such as EVA by means of the film **3**F, the overall layout of the plurality of solar cells, and the like. The dimension of the intervals L**3** and L**4** is determined in accordance with, for example, the size of the solar cells, manufacturing steps of the solar cells, and the like.

In the present embodiment, the cushion rubber **5**R has a generally octagonal shape in a plan view, and is provided between the transparent resin **3**R (the film **3**F) of the solar cell

unit **3** and the reinforcement **6**R. The cushion rubber **5**R is provided separately from the solar cell unit **3** (the transparent resin **3**R). As shown in FIG. **6**, an adhesive **5**G is preferably provided between the cushion rubber **5**R and the reinforcement **6**R. The cushion rubber **5**R is provided at a position corresponding to the intervals L**3** and L**4** left between the solar cells **3**C**1** to **3**C**4**.

In other words, defining a region formed by the intervals L**3** and L**4** (a region where no solar cell is provided) as a clearance region, the cushion rubber **5**R is provided at a position corresponding to this clearance region. In a plan view, the cushion rubber **5**R has an area smaller than that of this clearance region. When the cushion rubber **5**R (the upper surface of the cushion rubber **5**R) is projected onto the clearance region and the reinforcement **6**R, the projected image of the cushion rubber **5**R (the upper surface of the cushion rubber **5**R) is entirely included in the projected image of the clearance region and the reinforcement **6**R.

In a plan view, a distance L**5** (FIG. **5**) between the outer edge the cushion rubber **5**R and the outer edge **3**E**3** of the solar cell **3**C is 3 mm to 5 mm, for example. The cushion rubber **5**R is configured and arranged as described above. The reinforcement **6**R supports the solar cell unit **3** through the cushion rubber **5**R interposed therebetween.

(Positioning Part **5**S)

FIG. **7** an enlarged view showing a region encircled with the line VII in FIG. **2**. FIG. **7** illustrates four of the plurality of solar cells **3**C (**3**C**5** to **3**C**8**) arranged in two rows and two columns, the reinforcement **6**R, the roof panel **4**P, and a positioning part **5**S. The positioning part **5**S has a portion (a boss **5**S**2**) protruding from the solar cell unit **3** toward the reinforcement **6**R. FIG. **8** is a cross sectional view taken along the line VIII-VIII in FIG. **7**.

The interval L**1** is left between the outer edges **3**E**1** of the solar cells **3**C**5** and **3**C**6** adjacent to each other in the vehicle width direction. The interval L**1** is also left between the outer edges **3**E**1** of the solar cells **3**C**7** and **3**C**8**. The interval L**2** is left between the outer edges **3**E**2** of the solar cells **3**C**5** and **3**C**7** adjacent to each other in the vehicle longitudinal direction. The interval L**2** is also left between the outer edges **3**E**2** of the solar cells **3**C**6** and **3**C**8**. The interval L**3** is left between the outer edges **3**E**3** of the solar cells **3**C**5** and **3**C**8** adjacent to each other in an oblique direction. The interval L**4** is left between the outer edges **3**E**3** of the solar cells **3**C**6** and **3**C**7** adjacent to each other in an oblique direction.

The positioning part **5**S includes a boss seat **5**S**1** and the boss **5**S**2** (projection). The boss seat **5**S**1** and the boss **5**S**2** are made of polycarbonate, for example. The boss seat **5**S**1** has a generally octagonal shape in a plan view. The positioning part **5**S is fixed to the roof panel **4**P. The positioning part **5**S is preferably integrated with the roof panel **4**P by a double molding method or the like. The boss **5**S**2** has a shape extending in the form of rod from the solar cell unit **3** toward the reinforcement **6**R. The reinforcement **6**R has a circular opening **4**H formed therein, and the size and shape of the opening **4**H are set such that the boss **5**S**2** can be inserted into the opening **4**H.

The positioning part **5**S is provided at a position corresponding to the intervals L**3** and L**4** left between the solar cells **3**C**5** to **3**C**8**. Defining a region formed by the intervals L**3** and L**4** (a region where no solar cell is provided) as a clearance region, the positioning part **5**S has an area smaller than that of this clearance region in a plan view. When the positioning part **5**S is projected onto the clearance region and the reinforcement **6**R, the projected image of the positioning part **5**S is entirely included in the projected image of the clearance region.

In a plan view, the distance L**5** (FIG. **7**) between the outer edge the positioning part **5**S (the boss seat **5**S**1**) and the outer edge **3**E**3** of the solar cell **3**C is 3 mm to 5 mm, for example. The reinforcement **6**R is positioned by inserting the positioning part **5**S into an opening **3**H.

Referring again to FIGS. **2** and **3**, when seeing at one reinforcement **6**R, the plurality of positioning parts **5**S configured as described above are provided one each at the center and the both ends in the vehicle width direction, and the plurality of cushion rubbers **5**R are provided therebetween. For the sake of description, the positioning parts **5**S and the cushion rubbers **5**R shown in FIG. **2** are indicated by two different types of hatchings (upward sloping and downward sloping), respectively, for distinction between them. The positioning parts **5**S provided one each at the center and the both ends in the vehicle width direction can fulfill a high positioning function, and the plurality of cushion rubbers **5**R offer high damping performance and shock-absorbing characteristics.

(Fixing Structure)

Referring again to FIGS. **2** and **4**, a bracket **7** and fasteners **8** are used in order to fix the solar cell unit **3**, the roof panel **4**P and the reinforcements **6**R to roof side rails **6** of the vehicle **10** (FIG. **1**). The roof side rails **6** each include a side member outer panel **6**T and a rail inner panel **6**S, and extend in the vehicle longitudinal direction at the both side edges in the vehicle width direction.

One end of the bracket **7** closer to the roof side rail **6** is fixed to the rail inner panel **6**S with the fastener **8**, and the other end of the bracket **7** closer to the reinforcement **6**R is fixed to the reinforcement **6**R with another fastener **8**. The reinforcement **6**R is supported in a bridging manner at the both ends thereof by the roof side rails **6** on the left and right sides, with the bracket **7** on the left side of the vehicle and the bracket **7** (not shown) on the right side of the vehicle interposed therebetween, respectively. It is noted that the brackets **7** are not necessarily provided, but the reinforcements **6**R may be attached directly to the roof side rails **6**.

The reinforcement **6**R and the bracket **7** are secured with the fastener **8** to constitute a unit. As for the roof panel **4**P and the roof side rails **6**, the clearance left between the periphery of the vehicle inner-side end of the roof panel **4**P and each of the roof side rails **6** is filled with a urethane-based adhesive **9** (FIG. **4**). Then, the unit of the reinforcement **6**R and the bracket **7** is positioned utilizing the above-described positioning part **5**S (FIG. **8**) to be attached to the solar cell unit **3** and the roof panel **4**P. The unit of the reinforcement **6**R and the bracket **7** is then fixed to the roof side rail **6** with the fastener **8**.

(Functions and Effects)

As described at the beginning, loads are imposed on the vehicle roof by snow coverage, car washing or the like. Let it be supposed that the supporting parts **5** including the cushion rubbers **5**R and the positioning parts **5**S are provided at positions overlapping the solar cells **3**C in a plan view. In this case, when a load is imposed on the vehicle roof, the solar cells **3**C will suffer from stress resulting from the load. The solar cells may break down so that they can no longer generate electric power appropriately.

In contrast, referring to FIG. **9**, in the present embodiment, the cushion rubber **5**R is provided at a position corresponding to the intervals left between the solar cells **3**C adjacent to each other. Even when a load is imposed on the vehicle roof, stress resulting from the load will be mainly imposed on the transparent resin **3**R (where none of the solar cells **3**C is provided) positioned between the solar cells **3**C adjacent to each other. Stress is effectively prevented from being imposed on the

solar cells, which can achieve a structure in which the solar cells **3**C are unlikely to break down. It may be configured such that the mounting density of the solar cells **3**C is as large as possible by utilizing the clearances left between the solar cells **3**C as described above.

In the present embodiment, the roof panel **4**P made of resin is used. The use of the roof panel **4**P made of resin rather than a glass plate can provide an advantage in reducing the weight of the roof **1**, however, the reinforcements **6**R having a predetermined width are used as reinforcing members since the roof panel **4**P made of resin has rigidity lower than that of a glass plate. On the other hand, the solar cells are arranged in a planar form such that the interval between the solar cells adjacent to each other is smaller in general in order to increase the mounting density thereof. Therefore, the width of the reinforcements **6**R may be larger than the interval between the solar cells **3**C adjacent to each other depending on the strength required of the reinforcements **6**R and the interval between adjacent solar cells.

When the width of the reinforcements **6**R is larger than the interval between the solar cells **3**C adjacent to each other, and assuming that the solar cell unit **3** is directly supported by the reinforcements **6**R without providing the cushion rubbers **5**R, ends of the cells will interfere with the reinforcements **6**R in the cross sectional vertical direction. Then, the cells may receive excess stress and break down. Herein, when cutting up cells (single crystal cells) from a typical cylindrical ingot to form the solar cells **3**C, the solar cells **3**C can have an octagonal shape with the corners of a rectangular shape removed. With the four corners provided for the solar cells **3**C, relatively large clearances are left between the plurality of solar cells **3**C when arranged in a matrix form. In the present embodiment, these clearances are utilized positively to arrange the cushion rubbers **5**R and the positioning parts **5**S. Therefore, the present embodiment can achieve a structure in which stress can effectively be prevented from being imposed on the solar cells **3**C, and in addition, the clearances are effectively utilized, and in turn, the mounting density of the solar cells **3**C can effectively be improved.

In the present embodiment, the positioning part **5**S (FIG. **8**) is also provided at a position corresponding to the intervals left between the solar cells **3**C adjacent to each other. When the positioning part **5**S is fixed to the reinforcement **6**R, a similar phenomenon may take place as in the case described with reference to FIG. **9**. That is, even when a load is imposed on the vehicle roof, stress resulting from the load will be mainly imposed on the transparent resin **3**R (where none of the solar cells **3**C is provided) positioned between the solar cells **3**C adjacent to each other. A structure can be achieved in which stress is effectively prevented from being imposed on the solar cells **3**C from the positioning part **5**S, so that the solar cells are unlikely to break down.

Referring to FIG. **10**, when assembling the reinforcement **6**R to the solar cell unit **3**, it is assumed that the boss **5**S**2** is not successfully inserted into the opening **4**H, but the lower end of the boss **5**S**2** is brought into contact with the surface of the reinforcement **6**R. A structure can be achieved in which, even in such a case, stress is effectively prevented from being imposed on the solar cells **3**C, so that the solar cells are unlikely to break down.

In the present embodiment, it is possible to achieve predetermined rigidity and also achieve weight reduction by the roof panel **4**P made of a transparent resin and the plurality of reinforcements **6**R. The overall weight can be made lighter by adopting the reinforcements **6**R to increase rigidity without making the thickness of the roof panel **4**P very thick, than when increasing the thickness of the roof panel **4**P to increase rigidity. The overall weight can be made lighter even in consideration of the additional weight of the reinforcements **6**R than in the case of using a glass panel.

As described above, the solar cells **3**C of the present embodiment are sealed with a transparent thermoplastic resin, such as EVA (Ethylene Vinyl Acetate). By the method of sealing with EVA, a process step takes a shorter time than in the method of enclosing solar cells in FRP, so that productivity can be improved.

[First Variation]

As a vehicle roof structure **2**A shown in FIG. **11**, the supporting part may include a raised part **5**Q. The raised part **5**Q can be used instead of the cushion rubber. The raised part **5**Q is formed by solidifying the transparent resin **3**R with a projecting part **4**Q previously provided on the lower surface of the roof panel **4**P. The raised part **5**Q is a section integrally formed with the solar cell unit **3**, and is shaped such that part of the transparent resin **3**R sealing the solar cells **3**C is raised toward the reinforcement **6**R. The reinforcement **6**R supports the solar cell unit **3** sealed with the transparent resin **3**R with the raised part **5**Q interposed therebetween. With this structure, functions and effects similar to those described above can also be obtained.

[Second Variation]

As a vehicle roof structure **2**B shown in FIG. **12**, supporting parts may be provided at positions corresponding to the intervals between two of the plurality of solar cells **3**C adjacent to each other. In FIG. **12**, the cushion rubber **5**R is provided between solar cells **3**CA and **3**CB adjacent to each other in the vehicle longitudinal direction. The cushion rubber **5**R has a shape extending in the vehicle width direction. The supporting part **5** including the cushion rubber **5**R and the positioning part **5**S may be provided between the solar cell **3**CA and a solar cell **3**CC adjacent to each other in the vehicle width direction. With these structures, functions and effects similar to those described above can also be obtained.

[Other Variations]

In the above-described embodiment, the cushion rubber **5**R (FIG. **6**) as the supporting part and the positioning part **5**S (FIG. **8**) are employed. This structure is not a limitation, but the positioning part **5**S may be configured to have both the positioning function and the supporting function as the supporting part, or the cushion rubber **5**R (the supporting part) may have the function of the positioning part. Even in such a case, the effect can be obtained in which the solar cells can be prevented from breaking down under stress since the positioning part and the supporting part are provided utilizing the position corresponding to the intervals left between the plurality of solar cells. The cushion rubber, the positioning part and the raised part can be embodied in combination or alone.

The supporting part may be implemented by a member not having the cushioning function. Even in such a case, the effect can be obtained in which the solar cells can be prevented from breaking down under stress by providing the supporting part at the position corresponding to the intervals left between the plurality of solar cells.

In the above-described embodiment, the reinforcement **6**R has the opening **4**H. The opening **4**H is not limited to the shape of through-hole, but may have a recessed shape. This structure is not a limitation, but an opening (recess) may be provided on the solar cell unit **3** (the transparent resin **3**R) side, and the positioning part may be provided on the reinforcement **6**R side. In other words, as long as the positioning function can be effected, one of the reinforcement **6**R and the transparent resin **3**R may be provided with an opening, and the positioning part **5**S may be fixed to the other one of the reinforcement **6**R and the transparent resin **3**R. Even in these

cases, the effect can be obtained in which the solar cells can be prevented from breaking down under stress by providing the supporting part at the position corresponding to the intervals left between the plurality of solar cells.

In the above-described embodiment, the reinforcements **6**R having a shape extending in the form of rod are used as the reinforcing members. The reinforcing members are not limited to the rod-like members, but may be implemented by a plate-like member such as a flat plate or a curved plate. The plate-like member may have a size similar to that of the roof panel **4**P, or may have a structure divided into a plurality of pieces.

In the above-described embodiment, the reinforcements **6**R each have a rectangular tube-shaped (generally quadrilateral) cross section. The reinforcements **6**R may have a cylindrical or a columnar cross section, or may have a C- or U-shaped cross section, or may have a hat-shaped cross section. The cross section of the reinforcement (reinforcing member) is preferably determined to assume a shape having the optimum moment of inertia of area depending on required rigidity.

The above-described reinforcements **6**R are disposed to extend in the vehicle width direction. The reinforcements **6**R may be disposed to extend in the vehicle longitudinal direction, or those extending in the vehicle width direction and those extending in the vehicle longitudinal direction may be combined together.

Although the embodiment of the present invention has been described, it should be understood that the embodiment disclosed herein is illustrative and non-restrictive in every respect. The scope of the present invention is defined by the claims, and is intended to include any modification within the meaning and scope equivalent to the terms of the claims.

What is claimed is:

1. A vehicle roof structure, comprising:

a solar cell unit having a plurality of solar cells arranged in a planar form at intervals from one another and a sealing resin sealing said plurality of solar cells;

a roof panel having transparency and disposed to cover said solar cell unit from above; and

a reinforcing member disposed under said solar cell unit,

said reinforcing member supporting said solar cell unit with a plurality of supporting parts provided at positions corresponding to the intervals left between said plurality of solar cells.

2. The vehicle roof structure according to claim **1**, wherein

said plurality of supporting parts include cushion rubbers provided separately from said solar cell unit, and

said reinforcing member supports said solar cell unit with said cushion rubbers interposed therebetween.

3. The vehicle roof structure according to claim **1**, wherein

said plurality of supporting parts each include a raised part formed integrally with said solar cell unit and formed such that part of said sealing resin is raised toward said reinforcing member, and

said reinforcing member supports said solar cell unit with said raised part interposed therebetween.

4. The vehicle roof structure according to claim **3**, wherein

said roof panel includes a projecting part formed integrally with said roof panel at a position corresponding to said intervals left between said plurality of solar cells, and

said raised part is formed by providing said projecting part for said roof panel.

5. The vehicle roof structure according to claim **1**, wherein

said solar cell unit includes a positioning part at a position corresponding to the intervals left between said plurality of solar cells, and

said reinforcing member is positioned at said solar cell unit with said positioning part.

6. The vehicle roof structure according to claim **5**, wherein

said reinforcing member has an opening, and

said positioning part has a projection being fixed to said roof panel and extending in a rod-like form from said sealing resin toward said reinforcing member.

7. The vehicle roof structure according to claim **1**, wherein

said plurality of solar cells are arranged in a matrix form, and

said plurality of supporting parts include said supporting parts provided at positions corresponding to said intervals left between four of said plurality of solar cells arranged in two rows and two columns.

8. The vehicle roof structure according to claim **1**, wherein

said plurality of supporting parts include said supporting parts provided at positions corresponding to said intervals left between two of said plurality of solar cells adjacent to each other.

9. The vehicle roof structure according to claim **1**, wherein said reinforcing member includes a plurality of reinforcements each being implemented by a metallic member and disposed to extend in a vehicle longitudinal direction and/or a vehicle width direction.

10. The vehicle roof structure according to claim **1**, wherein said roof panel is made of resin.

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